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Emergency Medical Services Utilization And Interventions By Paramedics During A Blizzard

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EMERGENCY MEDICAL SERVICES UTLIZATION AND INTERVENTIONS BY PARAMEDICS DURING A BLIZZARD.

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On February 8th, 2013, southern Connecticut was struck by a powerful blizzard. Emergency Medical Services (EMS) crews experienced significantly increased call volume along with increased response and transport times. This study examined which types of EMS calls increased or decreased during the storm and whether paramedics performed more or fewer advanced life support (ALS) interventions.

EMS calls were differentiated by call type and analyzed to determine which types increased or decreased significantly during the blizzard. Then electronic patient care reports were searched for interventions by paramedics and analyzed to determine whether calls with interventions increased or decreased.

During the storm, average calls per day increased from 196 to 249 ($p=0.001$). Statistically significant increases ($p<0.05$) were seen for the following call types: abdominal pain, breathing problems, carbon monoxide, diabetic problems, pregnancy, cardiac calls, and unknown type. The rate at which transporting paramedic units performed an intervention decreased during the storm but this decrease was not statistically significant ($p=0.09$).

The findings may suggest that the higher EMS call volume was due to an increase in lower acuity patients without a corresponding increase in higher acuity patients. Planning for future blizzards therefore may best be met with increased staffing of emergency medical technicians without an increase in paramedic personnel or equipment.

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Introduction

The storm:

On Friday, February 8th, 2013, a blizzard struck southern Connecticut. Snow began to fall in the early afternoon and was falling steadily across the region by evening. When the snow ended the following day, New Haven, CT, had 34 inches of snow on the ground and 40 inches had accumulated in the nearby town of Hamden (1). These totals surpassed the average snowfall in the area for an entire winter, 30-35 inches (2), and represented the greatest accumulation in a single storm since 1888 (3). Roads were impassable so New Haven issued a travel ban and deployed police officers to several entrance points to the city to deter non-essential visitors from entering (4).

As towns attempted to remove snow, emergency services were inundated with calls, both storm-related and routine. Emergency Medical Services (EMS) in the New Haven area experienced a sharp increase in call volume that lasted until Wednesday, February 13th. While all emergency services suffered delayed response times due to the snow, EMS faced the additional challenge of transporting patients to hospitals despite road conditions. During the storm, average EMS response times increased from five to nine and a half minutes and average transport times increased from 12 to 17.5 minutes (5).

EMS in Southern Connecticut:

After the Yale Trauma Study (6) found prehospital care in Connecticut to be inadequate, the state enacted legislation (7) to organize EMS response. Each town is entitled to administer EMS within its primary service area (PSA) and EMS responders are certified as: emergency medical responders (EMRs), emergency medical technicians (EMTs) or paramedics.

EMRs are often police officers or firefighters who are trained to render first aid and can defibrillate cardiac arrest victims with an automated external defibrillator. They cannot assume responsibility for transporting patients to the hospital and must transfer care to EMTs or paramedics.

EMTs (also known as basic life support (BLS) providers) can do anything allowed an EMR and can also provide oxygen through various delivery devices, stabilize injuries more extensively, and assist patients to administer certain of their home medications (such as nitroglycerin for chest pain and epinephrine auto-injectors for anaphylaxis). Unlike EMRs, BLS units may arrive at emergencies in an ambulance and can transport patients to the hospital. Paramedics (also known as advanced life support (ALS) providers), in addition to providing BLS level care, carry cardiac monitors that have both diagnostic capability (three-lead and twelve-lead ECGs) and therapeutic capability (defibrillation, transcutaneous pacing and synchronized cardioversion). Among other skills, ALS units obtain intravenous (IV) or intraosseous (IO) access and provide medications. For patients with asthma or chronic obstructive pulmonary disease (COPD), they administer nebulized albuterol and ipratropium. They also perform endotracheal intubation and other forms of advanced airway management, including emergency cricothyrotomy.

In Connecticut, prehospital care is supervised by medical directors from local "sponsor" hospitals who draft protocols and oversee radio communications allowing EMTs and paramedics to consult with emergency physicians in real-time. In southern Connecticut, the Yale New Haven Sponsor Hospital Program (YNHSHP) oversees EMS for the following twelve towns: Bethany, Branford, East Haven, Guilford, Hamden, Madison, New Haven, North Branford, North Haven, Orange, West Haven, and Woodbridge. In 2013, this area had an estimated population of 411,876 people (8). **Figure 1** shows the YNHSHP territory.

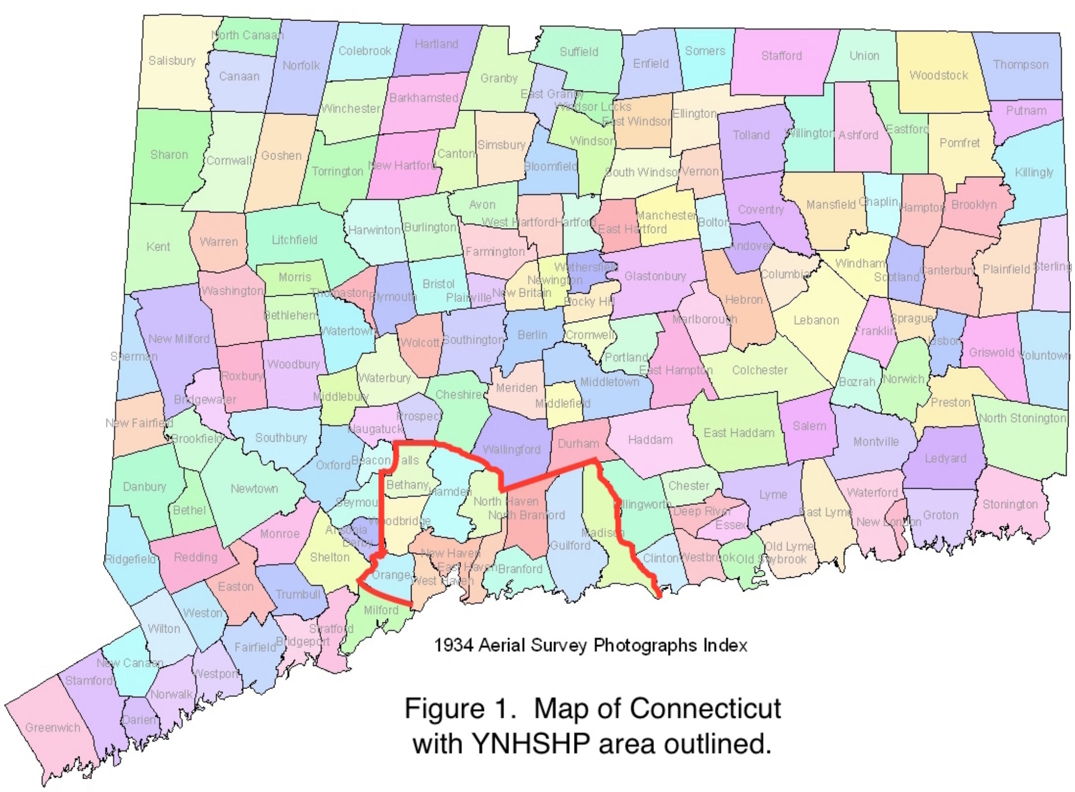


Figure 1. Map of Connecticut with YNHSHP area outlined.

Impacts of Snow on Health:

Although little has been published about the effects of snow on EMS, the medical literature has approached the effects of snow on healthcare from several angles. Since the 1970s, cardiologists and epidemiologists have studied whether snowfall is a risk factor for cardiovascular disease and have shown that people suffer cardiac events while shoveling snow after blizzards (9). Trauma surgeons, using their comprehensive patient registries, began in the 1990s to assess the extent to which weather conditions, including snowfall, influence the volume and nature of trauma admissions (10). Finally, in recent years more attention has turned to the danger of carbon monoxide (CO) poisonings and how much this risk is increased in blizzards (11).

After a powerful blizzard blanketed New England in February 1978, Glass et al. (12) reported that in Massachusetts, 27 deaths were considered "storm-related," including six men who suffered cardiac arrest while shoveling snow. However, the authors did not explain what criteria were used to determine that a death was "storm-related." They also concluded that overall mortality in Massachusetts did not increase as a result of the storm. Writing about the same blizzard, Faich and Rose (13) surveyed visits to 10 emergency departments (EDs) in Rhode Island and found that while visits decreased for several days after the snowfall, they quickly returned to normal levels in the days afterward. Looking for effects on cardiac health, they found that hospital admissions for angina or myocardial infarction (MI) increased from 17.6 daily in their control period to 28 daily in the third and fourth days after the storm. They also saw a concurrent increase in death from cardiac causes and explained that, "The transient increase in ischemic heart deaths associated with the blizzard was almost certainly due to an increase in physical and psychological stress." The chief physical stress they implicated was snow shoveling. Importantly, the authors observed that healthcare demand peaked several days after the snowfall rather than during the storm.

Combining data from the 1978 blizzard with those from five other storms, Glass and Zack (14) determined that in weeks of blizzards there was a 22% increase in deaths from ischemic heart disease (IHD). They commented: "IHD deaths were increased for 8 days after a snowstorm, suggesting that the effect was related to activities such as snow shovelling [sic] rather than the storm itself." Blindauer et al. (9) performed an ED chart review study looking for significant changes in ED visits in Suffolk County, NY after the 1996 blizzard there. Using a blizzard period that they defined as lasting five days from initial snowfall, they looked at the following conditions, which they hypothesized may have significantly increased or decreased: hypothermia, frostbite, CO poisoning, MI, angina, asthma, chronic obstructive pulmonary disease (COPD), and social/behavioral conditions. They found that visits for angina or MI rose from five in the control period to 42 during the blizzard and that 21 of these patients attributed their chest pain to shoveling snow. The shovelers also had a higher admission rate, suggesting that their disease was more significant. However, the authors found no overall increase in ED visits during the storm. Among the conditions studied, MI/angina was the only one to significantly increase and asthma alone saw a significant decrease. It must be noted that this study, like its predecessors, may be confounded by confirmation bias, whereby researchers, attempting to find a positive correlation between blizzards and cardiac events, found what they were looking for.

In order to better meet staffing needs as well as to inform public policy on issues of road closures and school cancellations, trauma surgeons began to study the effect of weather on trauma admissions. Bhattacharya and Millham (15) analyzed trauma admissions at Boston Medical Center from 1992-1998. They found a statistically significant 12.8% decrease on days in which more than two inches of snow fell, but did not offer an explanation for these findings. Rising et al. (16), using data from the University of Louisville trauma center from 1996-2002, found no association between snow and trauma admissions. More recently, Ho et al. (17), looking at data from Jamaica Hospital in New York City between 2000-2009, found that increasing snow accumulation corresponded to significant increases in overall trauma and blunt trauma, but saw no change in penetrating trauma. In a review article, Ali and Willet (10) conceded that there were conflicting data on whether trauma admissions increase or decrease when it snows, but concluded that most studies leaned toward a decrease.

The relationship between weather and healthcare utilization for violent injury has also been directly studied. Bernstein et al. (18) examined whether Bat Day at Yankee Stadium—in which 25,000 baseball bats are distributed to fans 14 years old and younger—was associated with an increase in emergency department visits for assaults using those baseball bats. While the study did not find an association between Bat Day and visits for assault with baseball bats, it did report an association between visits for such assaults and increasing daily temperature.

Gamble and Hess (19) determined that violent crime increases with rising temperature until about 90 degrees Fahrenheit and then falls as the temperature rises further. Michel et al. (20) studies emergency visits for trauma to Johns Hopkins Hospital in Baltimore from 2007-2013. They found increased temperature to be the most important atmospheric determinant of visits due to “intentional injury” and also found a significant decrease in these visits during periods of snowfall. However, snow was not associated with a decrease in visits for gunshot wounds or overall trauma.

Studies associating carbon monoxide (CO) poisoning with blizzards date back at least to the New England blizzard of 1978. Glass et al. (12) attributed five storm deaths in Massachusetts to CO while Faich and Rose (13) reported that ED visits for CO in Rhode Island rose from one in the control to five in the blizzard. Blindauer et al. (9) saw an increase in ED visits for CO from two to five, which was not statistically significant. In 2014 Connecticut enacted legislation to greatly increase deployment of CO detectors (21). Johnson-Arbor et al. (11), using data from the February 2013 Connecticut blizzard, found 34 calls between 2/8/13 and 2/12/13 to the state poison control center in Hartford that referenced CO poisoning. The authors noted that the leading cause of CO exposure was blocked car exhausts and cautioned the public to check car tailpipes after a major snowfall.

This literature provides important insight into medical emergencies occurring during blizzards. As demonstrated in studies of the 1978 and 1996 blizzards, overall mortality and ED visits did not change significantly in blizzards, though specific conditions such as cardiac arrests increased. In some instances, blunt trauma increased as well. There were also consistent increases in CO poisoning, although the numbers of incidents and patients were small. This suggests that while overall healthcare utilization may not increase dramatically in a blizzard, patients' needs may be different from normal and different resources may be required to meet them. It must be determined whether these changes in cardiac emergencies, trauma and CO poisoning, along with other conditions, are reflected in EMS utilization and the care provided by ambulance crews.

EMS During Disasters:

In recent years, EMS disaster preparedness has undergone a transformation from relying on anecdote and expert opinion to using historical data to plan for unusual events (22). Operations researchers create computer models of storms and other significant events in order to predict staffing needs. They also review EMS operations during specific disasters to determine how resources were used and how they could have been better deployed (23, 24, 25). Public health researchers consider the role of EMS in helping to care for vulnerable populations, or people with increased health-care needs at baseline whose requirements in disasters may be different from and more urgent than those of the rest of the public (26). In several instances, EMS operations in snow have been directly studied (24, 25, 27).

Traditionally, many EMS agencies have relied on local expert opinion, informed by personal recollection of past events, to predict needs for disasters. For example, Kaiser (28), writing in the influential trade publication *Journal of Emergency Medical Services* (*JEMS*), recommended: "Think of unconventional assignments if you have a surplus of employees without ambulances. You may want to assign EMS personnel to other teams, mass-shelters or search-and-rescue operations." While any of these ideas may be worthwhile in a specific context, the author provided no data to substantiate whether any such reassignments were attempted in previous disasters and whether they were successful.

Responding to such data-deficient recommendations, Auf der Heide (22) emphasized the importance of data collection and analysis when planning for disasters. The author noted, however, that studying disasters is especially difficult. Typically, such studies are retrospective and it is difficult to appropriately measure desired outcomes. As expected, record keeping during disasters is often subpar and useful data are often lost or never recorded. Also, and perhaps most relevant for EMS research, studying a particular disaster in a particular area does not always result in meaningful information for a different type of disaster or different area.

Levy et al. (29) reported testing a specific disaster management tactic to determine whether it was efficacious. In the *JEMS* article, Kaiser had recommended reassigning EMS personnel to non-traditional roles. In their study of a 2010 blizzard in Columbia, Maryland, Levy et al. described a program in which a local fire department, recognizing that EMS call volume was lower during the snowfall phase of the storm, used their 911 ambulance crews to return discharged hospital patients to their homes. This freed hospital beds for the surge of new patients that arrived in the subsequent days, helping to reduce ED crowding. The authors' quantitative analysis of this program allows EMS and hospital administrators in other jurisdictions to determine whether a similar idea may be useful to them.

Operations researchers have long used data to optimize planning and they have constructed models for deploying ambulances in routine situations. More recently, researchers built models that account for specific weather conditions. Wong and Lai (23) used weather data and EMS call data to predict changes in ambulance demand depending on weather. However, their data were collected from Hong Kong, where snow is rare and therefore not one of the climate variables they considered. Importantly, the authors appreciated that, "The [EMS utilization] model could be strengthened if different types of ambulance demand could be identified." This suggests that breaking down EMS response by call type—the specific reason someone calls an ambulance—would help to determine which types of EMS resources (e.g. BLS, ALS, or non-transporting units) are needed more (or less) in different weather conditions.

In the most directly relevant operations research, McLay et al. (24) used three different regression methods to model EMS utilization in hurricanes and blizzards for a semi-rural, semi-suburban Virginia county. They found that, "The volume of 911 calls increases during extreme weather events and the nature of these 911 calls may be altered." Studying several pre-determined low priority and high priority call types that they considered representative, the authors concluded that the increase in 911 calls is due mainly to an increase in lower priority calls while the volume of higher priority calls stays the same. They also noted that overall call duration is actually shorter in extreme weather than their models predict, suggesting that, "EMS personnel may adapt to high call volumes during severe weather events by shortening response and service times."

In 2013, Kunkel and McLay (25) built models to determine ambulance staffing needs for four snowfall events of increasing severity in the same Virginia county. Contending with snow accumulation that blocks roads and produces other dangerous driving conditions, the authors found that "snow conditions may significantly increase the likelihood that an EMS system is unreliable and thus necessitates an increase in the number of ambulances that should be staffed." However, they did not examine call types to determine how increased demand is apportioned or how additional resources may be allocated. As in the previous paper, they noted the phenomenon of "intrinsic system adaptation" and concluded that it "has similar effects on system reliability as one additional ambulance."

Thorns et al. (27), in 2014, were the first to comprehensively study the correlation between weather and call type. The authors attempted to study the effects of weather on EMS longitudinally, looking at the correlation between weather and EMS utilization over a three and a half year period in Birmingham, UK. They found a significant correlation between snow and patients calling the ambulance for falls. They also noted an increase in calls for patients for breathing problems when it was snowing, but had trouble differentiating this from the increase in such calls that they regularly saw in colder weather. In another paper that looked for trends in EMS utilization in changing weather, Vencloviene et al. (30) studied 3,631 EMS calls that resulted in admission to a cardiology unit and found such calls positively correlated with lower temperature, lower barometric pressure, higher relative humidity and higher wind speed. However, the authors did not directly study snow. Also, their dataset of calls that resulted in hospital admissions is less useful from an EMS perspective because the same ambulance resources are expended whether or not a patient is ultimately admitted to the hospital.

While the aforementioned articles looked at the correlation between weather and call type, there are few articles that look at the changes in all call types during a specific disaster event. The two articles that do this are about, respectively, a hurricane and a blackout. No such articles about a blizzard could be found.

Cooper et al. (31) analyzed the effect of Hurricane Ike (2008) on the EMS system in Houston, TX. They found that call volume increased 40% during the storm period with the greatest increases in the following call types: respiratory problems, falls, and chest pain. The only significant decrease was in calls for motor vehicle crashes (MVCs), which they attributed to many fewer drivers on the roads during the storm. Freese et al. (32) studied EMS calls in New York City during a 29-hour blackout in 2003. They found a doubling of calls during the blackout compared to a control (7844 vs. 3860) and statistically significant increases in 20 of 62 call types that were used by the Fire Department of New York (FDNY) dispatch system. Of note, these 20 call types included several for respiratory problems ("difficulty breathing," "critical asthmatic," "upper respiratory tract infection" and "asthmatic") as well chest pain ("cardiac condition") and falls ("injury" —FDNY does not use a specific "falls" call type). The only significant decreases were in calls for psychiatric emergencies and calls for alcohol or drug intoxication.

Looking at healthcare needs across different types of disasters, Nick et al. (26) discussed the unique needs of "vulnerable populations," whom they defined as people with "special health-care needs due to disability," either physical or mental.

They estimated that approximately 12% of the United States population is permanently in this category while up to 80% of Americans will at some time incur a disability that will render them temporarily unable to care for themselves. The authors noted that such patients often have complicated medical histories and that in disasters they are often treated by unfamiliar providers who lack access to their medical records. Recognizing a role for EMS, they highlighted a program in Boston wherein local EMS systematically helps patients to consolidate their medical information into a portable paper form so that they can carry it with them in a disaster and maintain access to it even when power outages render electronic medical records inaccessible. Appreciating these challenges, Jan and Lurie (30) advocated for the inclusion of members of vulnerable populations in disaster planning so that their unique needs can be best understood and addressed.

Many individuals who are considered members of vulnerable populations are at increased risk during disasters because they normally depend on technological devices that may become inoperable. Ochi et al. (34) explained that in power outages, patients dependent on ventilators, home nebulizers, oxygen generation equipment or refrigerated medications may decompensate or simply require EMS evacuation to a medical facility. Similarly, disasters that compromise infrastructure including roads, water supply or electricity for more than a day or two produce medical emergencies when patients run out of their normal, home medications and have no pharmacy access and chemically dependent individuals such as alcoholics and opiate or benzodiazepine addicts cannot replenish their supplies.

Two particularly vulnerable populations who are known to face unique challenges during disasters are renal failure patients who are dependent on dialysis and full-term pregnant women. Dent et al. (35) explained that dialysis facilities often close during weather-related disasters and that patients may be unable to reach the ones that remain open. This problem was especially acute during Hurricane Katrina in 2005 when thousands of dialysis patients went without life-sustaining treatments for extended periods. The authors recommended that as many patients as possible receive dialysis ahead of schedule in advance of forecasted storms so that they can remain stable for longer into the storm period. They also suggested that local agencies compile registries of dialysis patients so that emergency responders and public health workers can more efficiently provide aid.

In the 2013 Connecticut blizzard, dozens of dialysis patients called 911 seeking transportation to dialysis centers. Most centers in the region were able to reopen soon after the snowfall ceased, but many patients were unable to travel to them in their personal vehicles due to road conditions. EMS agencies attempted to accommodate these patients on an ad hoc basis, but only by diverting resources that already had to contend with the dramatically increased call volume (unpublished observation).

Whereas dialysis patients may be considered permanent members of a vulnerable population, pregnant women inhabit this category temporarily, most significantly during the peripartum period. Like dialysis patients, pregnant women typically access care by personal vehicle. When road conditions prevent them from safely driving to the hospital for childbirth, they are more likely to utilize EMS.

Recognizing that childbirth during disasters is especially complex, Haeri and Marcozzi (36) recommended that pregnant women stock up on water and other supplies before forecasted storms and review procedures for a safe birth at home, in case an ambulance does not arrive in time. Applying recommendations that are more broadly relevant in disasters, Ewing et al. (37) suggested that pregnant women maintain paper copies of their medical records in case they are forced to deliver with prehospital providers or physicians who lack access to their medical records.

Looking at the literature in aggregate, several trends emerge. EMS utilization for chest pain was seen to increase in blizzards, a hurricane and a blackout. This suggests the possibility that the increase in this condition is tied not to the specific nature of the disaster but rather to a period of stress in which overall EMS call volume is high. The same argument can be made for respiratory problems and falls. Further study is needed to determine which call types increase consistently in different types of disasters and which increase preferentially in certain types. Additionally, no studies to date look at whether paramedics render different treatments to patients during disasters. It is conceivable that the "intrinsic system adaptation" predicted by the operations researchers results in less treatment, so that ambulance crews use less time and fewer resources before returning to service to pick up the next patient. Alternatively, it is possible that paramedics, faced with possibly sicker patients and longer transport times due to poor road conditions, provide more treatment. Also, it must be determined whether increases in a particular call type result in increased treatment for those patients (e.g. do more calls for chest pain result in paramedics performing more twelve-lead ECGs?)

Statement of Purpose

By looking at dispatch data from the central medical emergency dispatch center (CMED) for the Yale New Haven Sponsor Hospital Program region, this study analyzed whether each call type increased or decreased significantly during the February 2013 blizzard. Then, by reviewing electronic patient care reports (ePCRs) completed by EMS crews, it determined whether calls with ALS interventions increased or decreased. These data can help provide predicted logistical requirements to prospectively plan which types of EMS resources—both personnel and equipment— to deploy in a blizzard.

Methods

Call Types Analysis:

EMS call logs were obtained from CMED for the period of 1/25/13-2/25/13 in order to capture data for the storm period and establish controls from the weeks preceding and following. First, calls from outside the twelve municipalities of the YNHSHP area were filtered out from the log. Second, duplicate calls were removed. (At inconsistent intervals, the CMED database, presented as a Microsoft Excel spreadsheet, used a row to repeat the date. The last call before this extra row was duplicated in the row immediately after. These duplicates were removed.) Third, calls that pertained to law enforcement resources only—and did not involve an EMS response—were removed. Calls were then separated into call type. In the CMED database, most calls were labeled with one of 33 designations, as determined by the Medical Priority Dispatch System of the National Academy of Emergency Medical Dispatch. **Table 1** shows these call types. A small minority of calls in the database were not designated with one of the 33 call types of the Medical Priority Dispatch System used by CMED. If these calls represented use of EMS resources in a manner similar to a typical 911 call (e.g. sending an ambulance to stand-by at an active fire scene), they were included and were grouped together as a 34th call type. If not, they were removed.

Table 1. CMED Call Types

	Call Type
1	Abdominal Pain/Problems
2	Allergies (reactions, stings, bites)
3	Animal Bites/Attacks
4	Assault/Sexual Attack
5	Back Pain (non-traumatic)
6	Breathing Problems
7	Burns (scalds) Explosions
8	Carbon Monoxide/Inhalation/Haz-mat
9	Cardiac or Respiratory Arrest
10	Chest Pain
11	Choking
12	Convulsions/Seizures

13 Diabetic Problems

14 Drowning

15 Electrocution/Lightning

16 Eye Problems/Injuries

17 Falls

18 Headache

19 Heart Problems/AICD

20 Heat/Cold Exposure

21 Hemorrhage/Lacerations

22 Industrial/Machinery Accidents

23 Overdose/Poisoning (ingestion)

24 Pregnancy/Childbirth/Miscarriage

25 Psychiatric/Abnormal Behavior/Suicidal

26 Sick Person

27 Stab/Gunshot/Penetrating Trauma

28 Stroke (CVA)

29 Traffic/Transportation Accident

30 Traumatic Injury (specific)

31 Unconscious/Fainting (near)

32 Unknown Problem (man down)

33 Transfer/Interfacility/Palliative

Once separated by call type, calls were divided into six-hour segments from 00:00 of 1/25/13 to 23:59 on 2/25/13 for a total of 128 segments. The storm period comprised the 21 segments between 18:00 on 2/8/13 and 23:59 on 2/13/13. The control for each call type comprised the averages of three 21-segment periods that matched the storm period by day of the week and time of day. For example, the first segment of the storm period—18:00 until 23:59 on Friday, 2/8/13—was matched with the average of the data from 18:00-23:59 on the two preceding Fridays (1/25/13 and 2/1/13) and the following Friday (2/15/13). Wilcoxon Signed-Rank tests were then performed for each of the 34 call types as well as for the data for all of the call types in aggregate. These Wilcoxon tests determined which call types increased or decreased significantly during the storm period compared to the control.

In two instances, call types of a similar nature were combined for analysis in order to better determine whether these conditions increased or decreased significantly. First, call type 10 (chest pain) was combined with call type 19 (heart problems/AICD) in order to better study all cardiac calls. Second, all call types that likely reflect traumatic injury were combined. These were: 4 (assault), 7 (burns), 17 (falls), 21 (hemorrhage/lacerations), 27 (stab/gunshot/penetrating trauma), 29 (traffic/transportation incidents) and 30 (traumatic injuries).

Then, for each call type, the number of calls within each six-hour segment was divided by the total number of calls across all 34 types for that segment in order to determine what proportion that type represented of the total call volume. Once again, this was performed for the 21 segments of the call period and matched against the average of three periods that served as the control. Wilcoxon Signed-Rank tests were then performed for each of the 34 call types. These tests determined whether each call type's proportion within the total call volume increased or decreased significantly during the storm period compared to the control.

<u>ALS Treatment Analysis</u>:

Data for ALS treatment came from ePCRs from two National Emergency Medical Services Information Services (NEMSIS) Project-compliant electronic databases that together house more than 90% of the ePCRs generated within the YNHSHP area. The first database comprises ePCRs from the following towns: Branford, Bethany, East Haven, Guilford, and Madison. Each of these towns provides its own EMS response, in most cases via its fire department. All of these towns except Bethany have both ALS and BLS transport capability. (Bethany has only BLS.) The second database includes ePCRs from the following municipalities: Hamden, New Haven, North Branford, North Haven, Orange, West Haven and Woodbridge. The preponderance of ePCRs in the second database are from the larger towns within the YNHSHP region (New Haven, Hamden and West Haven) while the ePCRs in the first database are from smaller towns.

The first database was queried for all calls between 1/25/13 and 2/27/13 that resulted in patient transport to any of four emergency departments: Yale New Haven Hospital (York St) adult ED, Yale New Haven Hospital (York St) pediatric (ED), Yale New Haven Hospital (Chapel St) ED, and Yale New Haven Shoreline

Medical Center ED. Of note, this database includes only calls that resulted in ED transports. Calls that resulted in a refusal of medical attention (RMA), treatment without transport, or in which a patient was pronounced dead in the field are not included.

The database was filtered in the following steps: First, ePCRs from calls that occurred in towns outside the YNHSHP area were removed. Second, duplicate calls were removed. Third, ePCRs from BLS units were removed. Fourth, ePCRs from calls that did not represent a 911 transport (e.g. an interfacility transfer) and ePCRs from units that transferred care to another ambulance crew were removed. (Although, in a small number of cases, ALS units treated patients before transferring care, these transfers were to other ALS units that then transported the patient and the treatment data were gathered from the transporting unit's ePCR.)

The remaining ePCRs therefore represent calls within the YNHSHP area in which an ALS unit transported a patient to an ED. Each of these ePCRs was then searched for documentation of any of the following interventions: intravenous (IV) access (either attempted or successfully obtained), administration of an IV medication, performance of twelve-lead ECG, administration of nebulized albuterol or ipratropium, endotracheal intubation (ETI), manual defibrillation, intraosseous access, aspirin administration, nitroglycerin administration, administration of continuous positive airway pressure (CPAP) and intramuscular (IM) or intranasal (IN) medication administration. An ePCR in which any of these interventions was documented was considered to represent a call in which an ALS intervention was performed.

The second database was similarly queried for all calls between 1/25/13 and 2/27/13. The filtering steps were identical to those used for the first database, with the exception that there were no duplicate entries that had to be removed. The remainder of the analysis was identical. (Unlike the first database, the second database included RMAs and calls in which the patient was pronounced dead in the field. However, these were a very small minority of calls and very rarely involved an ALS intervention. In order to ensure consistency with the cohort from the first database, they were excluded.)

Data from the two databases were then combined to create a sum total of available calls in the YNHSHP area. As in the call types analysis, the data were divided into six-hour segments, in this case 136 segments between the beginning of 1/25/13 and 23:59 on 2/27/13. (Using data from 2/26/13 and 2/27/13 allowed for the creation of a fourth block to use for the control period. Data from these two days is no longer available from CMED and therefore cannot be incorporated into the call types analysis.) The storm period once again comprised the 21 segments between 18:00 on 2/8/13 and 23:59 on 2/13/13. The control comprised the averages of four 21-segment periods that matched the storm period by day of the week and time of day. Wilcoxon Signed-Rank tests were then performed to determine whether the total number of transports by an ALS unit increased or decreased significantly during the storm as well as whether the number of calls in which an ALS intervention was performed increased or decreased significantly. Then, within each six-hour segment, the number of calls in which an ALS intervention was performed was divided by the total number of calls in which an

ALS unit transported in order to determine the rate at which transporting ALS units performed an ALS intervention. Using the same storm period and controls, a Wilcoxon Signed-Rank test was performed to determine whether this rate increased or decreased significantly during the storm. Wilcoxon tests were also conducted to determine whether calls in which any of the specific ALS interventions were performed increased or decreased significantly during the storm. Because they are sufficiently similar, calls in which nebulized albuterol alone was given were combined for analysis with calls in which albuterol+ipratropium was given.

This project was approved by the Human Investigation Committee at Yale University School of Medicine. I designed the overall research question, obtained the databases, manually filtered the data as described, then reduced the data as required to address the questions and finally selected and performed the statistical analysis.

Results

Call Types Analysis:

As shown in **Figure 2**, removal of extraneous data from the CMED database resulted in 6,555 calls between 1/25/13 and 2/25/13. As shown in **Figure 3**, when separated into calls per day, there was an increase in total call volume during the storm period.

The average number of calls per day from 1/25/13 to 2/25/13 was 205 ± 27. The average for the storm period was 249 ± 28. Of note, the range of calls per day during the storm was broad, with a lower than average volume of 198 calls while snow was falling on Saturday, 2/9/13, and a peak of 276 calls on the following day, Sunday, 2/10/13, when snowfall had ceased. The greatest number of calls in any six-hour segment from among all the data gathered was 99, between 12:00 and

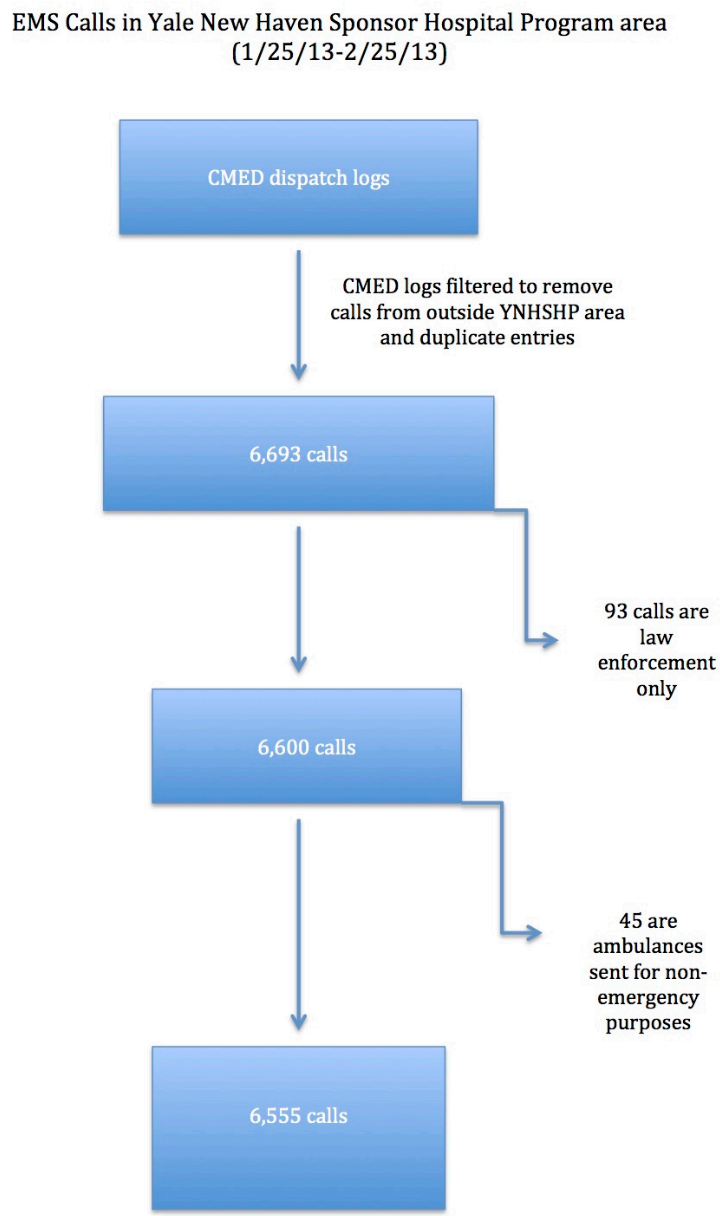


Figure 2. Steps of how CMED database was filtered to identify emergency ambulance calls in YNHSHP area.

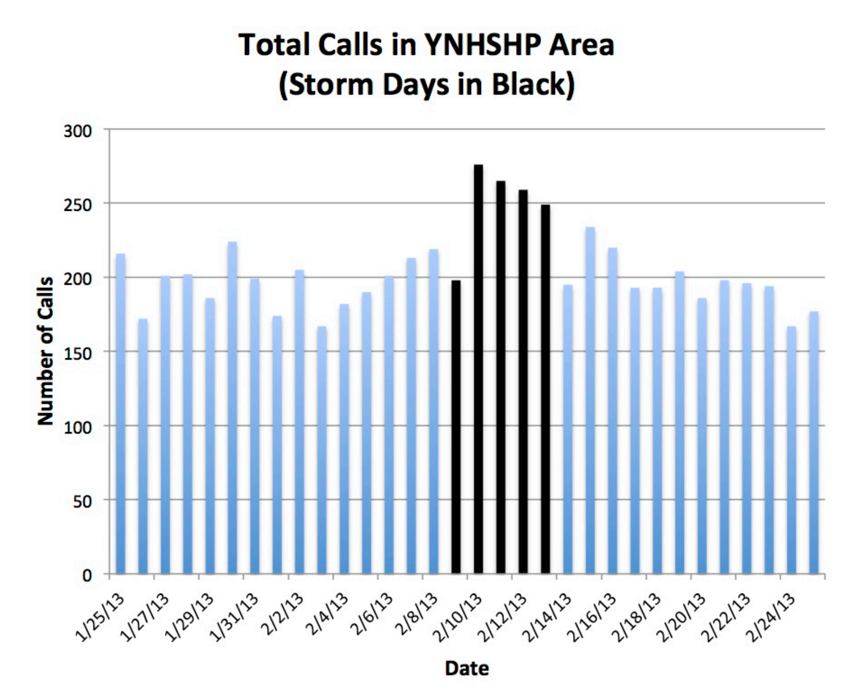


Figure 3. All calls distributed by day throughout the study period.

17:59 on 2/10/13. The increase in calls during the storm compared to the control was statistically significant (W-value of 23 with a critical W value of 58 for the N; p=0.001).

Throughout the study period, the six-hour segment of the day with the most calls was the segment from 12:00 to 17:59. **Figure 4** shows how call volume during this segment increased during the storm. **Figure 5** shows call volume separated by day of the week for each full day of the storm period. As shown in the embedded table, call volume on Saturday, 2/9/13, was average for that day of the week, while call volumes on the other four storm days were more than two standard deviations above the means for those respective days of the week.

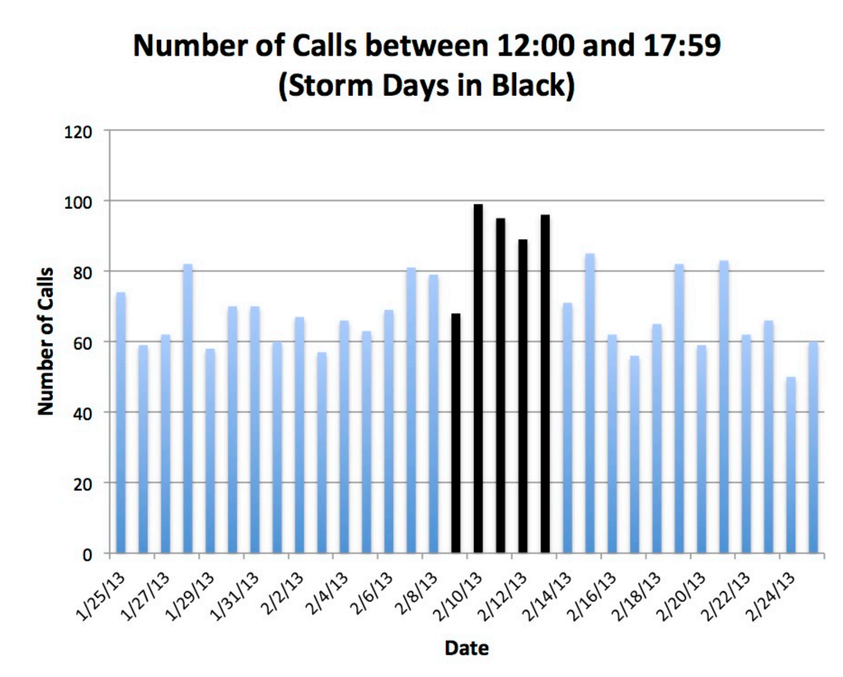
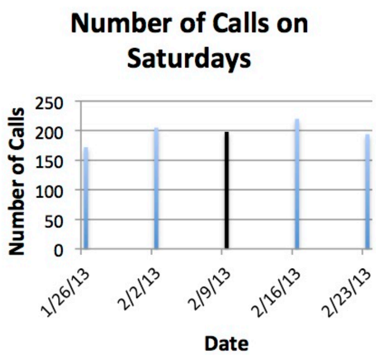
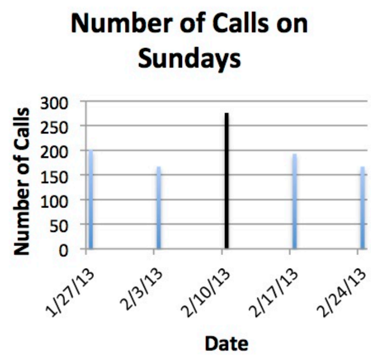
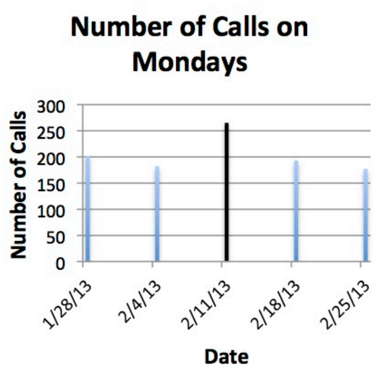


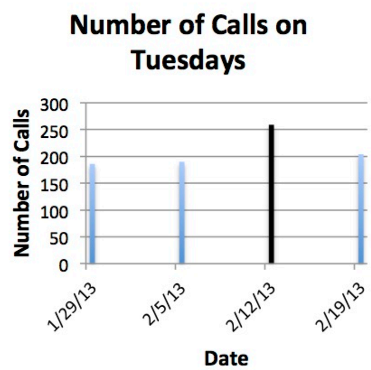
Figure 4. All calls between 12:00 and 17:59 distributed by day throughout the study period.

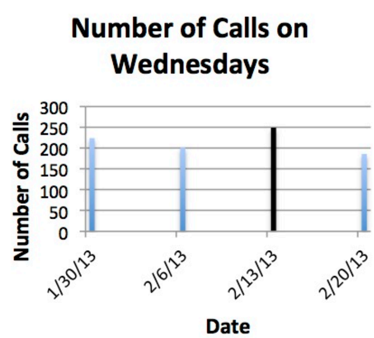
Number of Calls for Days of the Week
(Storm Days in Black)











Day	N/Day (Control)	N (Storm Day)
Saturday	198 ± 20	198
Sunday	182 ± 18	276
Monday	189 ± 11	265
Tuesday	193 ± 9	259
Wednesday	203 ± 19	249

Figure 5. Calls by day of the week for each full day in the storm period. The table at the bottom of the figure shows the mean number of calls on non-storm days vs. the number of calls on that day of the week during the storm.

As shown in **Table 2**, there was a wide variation in number of calls among the call types. Seven types had fewer than 10 calls for the entire period for which data were collected, while 15 types had more than 100 calls. Call Type 26—"Sick Person"—had 1,374 calls, representing 21% of the total volume. Eighteen call types increased in volume during the storm, seven of them significantly. Six types decreased, one of them significantly. As shown in **Figure 6**, the increase in calls for Call Type 24 —"Pregnancy/Childbirth/Miscarriage"— was especially dramatic, even though the total number of calls for this type was not high.

Table 2. Differences in Calls per Day for each Call Type

Call Type	N/day (Control)	N/day (Storm)	p value
1 Abdominal Pain/Problems	5.8	9.5	0.04

2	Allergies (reactions, stings, bites)	1.1	1.9	
3	Animal Bites/Attacks	0.3	0.6	
4	Assault/Sexual Attack	3.3	1.9	0.03
5	Back Pain (non-traumatic)	1.6	2.3	
6	Breathing Problems	22.9	32.4	0.04
7	Burns (scalds) Explosions	0.2	0.4	
8	Carbon Monoxide/Inhalation/Haz-mat	0.5	2.3	0.02
9	Cardiac or Respiratory Arrest	1	1.1	
10	Chest Pain	12.1	18.9	
11	Choking	0.6	0.2	
12	Convulsions/Seizures	4	6.1	
13	Diabetic Problems	3.6	7.2	0.007
14	Drowning	0	0	
15	Electrocution/Lightning	0	0.2	
16	Eye Problems/Injuries	0.2	0.2	
17	Falls	19	21.1	
18	Headache	0.4	0.6	
19	Heart Problems/AICD	2.6	4.4	
20	Heat/Cold Exposure	0.1	0.8	
21	Hemorrhage/Lacerations	4.7	6.3	
22	Industrial/Machinery Accidents	0	0	
23	Overdose/Poisoning (ingestion)	4.5	3	
24	Pregnancy/Childbirth/Miscarriage	1.4	4.2	0.009

25 Psychiatric/Abnormal Behavior/Suicidal	19.9	13.7	
26 Sick Person	40.5	55.4	0.001
27 Stab/Gunshot/Penetrating Trauma	0.3	0	
28 Stroke (CVA)	3	3	
29 Traffic/Transportation Accident	12.7	10.7	
30 Traumatic Injury (specific)	2.9	4.6	
31 Unconscious/Fainting (near)	7	7.6	
32 Unknown Problem (man down)	15.6	23.4	0.02
33 Transfer/Interfacility/Palliative	3.4	4.4	
34 Other	1	0.8	
Total	196.1	249.1	0.001

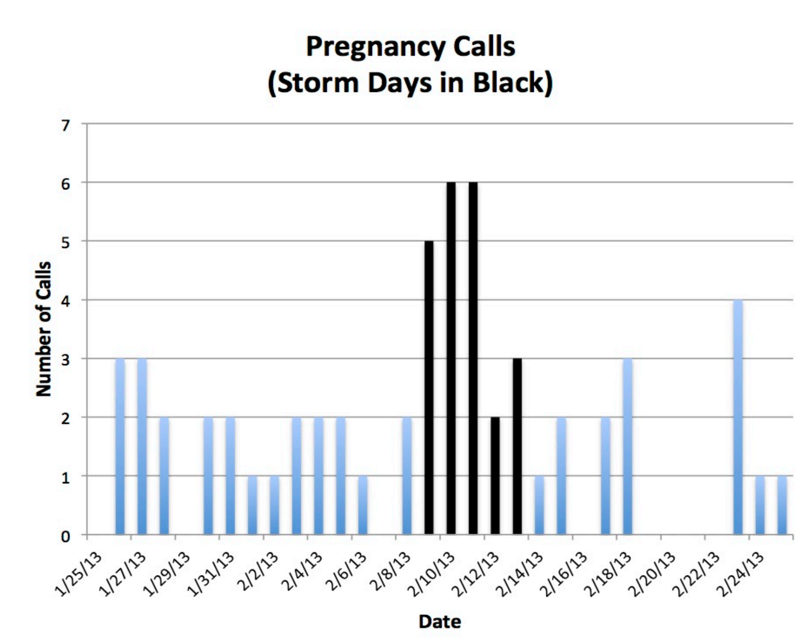


Figure 6. Pregnancy calls distributed by day throughout the study period.

As shown in **Figure 7**, the decrease in calls for Call Type 4 —"Assault"— was notable, but not unprecedented for the study period; a period of the same length from the evening of 2/17/13 until the end 2/22/13 saw eight assault calls compared to the 10 of the storm period. For the two instances in which call types were combined, all cardiac calls (call types 10 and 19) increased significantly during the storm (W value of 27.5 with a critical W value for the N of 46, p=0.007). The trauma calls (call types 4, 7, 17, 21, 27, 29 and 30) underwent an insignificant increase (W value of 92.5 with a critical W value of 52 for the N, p=0.64).

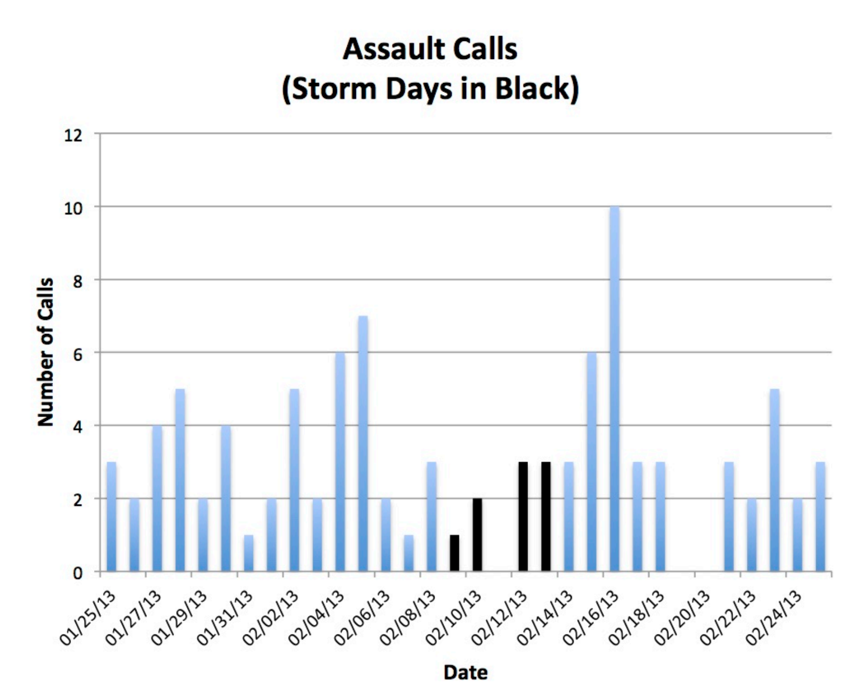


Figure 7. Assault calls distributed by day throughout the study period.

Table 3 also accentuates the wide variation in number of calls between call types. Sixteen call types each account for less than 1% of the total, while just four (sick person, breathing problems, falls, and psychiatric) combine for just over 50%. When considering, for example, that carbon monoxide calls increased significantly during the storm—both in total number and as a percent of the total—it must be noted that this type represented only 1% of call volume during the storm. However, the increase in calls for breathing problems is perhaps more meaningful given that this type comprises over 12% of overall volume.

Table 3. Percent of Total Call Volume for each Call Type

Call Type	% Total (Control)	% Total (Storm)	p value
1 Abdominal Pain/Problems	2.6	4.8	
2 Allergies (reactions, stings, bites)	0.4	0.9	
3 Animal Bites/Attacks	0.1	0.02	
4 Assault/Sexual Attack	2.1	1	0.01
5 Back Pain (non-traumatic)	1.2	1	
6 Breathing Problems	12.6	12.7	
7 Burns (scalds) Explosions	0.1	0.1	
8 Carbon Monoxide/Inhalation/Haz-mat	0.3	1	0.04
9 Cardiac or Respiratory Arrest	0.5	0.5	
10 Chest Pain	6.9	7.4	
11 Choking	0.2	0.1	
12 Convulsions/Seizures	1.8	2.4	
13 Diabetic Problems	1.8	2.8	

14	Drowning	0	0	
15	Electrocution/Lightning	0	0.1	
16	Eye Problems/Injuries	0.1	0.1	
17	Falls	10.2	8.3	
18	Headache	0.2	0.2	
19	Heart Problems/AICD	1.3	1.7	
20	Heat/Cold Exposure	0.1	0.3	
21	Hemorrhage/Lacerations	2.5	2.5	
22	Industrial/Machinery Accidents	0	0	
23	Overdose/Poisoning (ingestion)	2.7	1.2	0.02
24	Pregnancy/Childbirth/Miscarriage	0.8	1.7	0.009
25	Psychiatric/Abnormal Behavior/Suicidal	10	6.1	0.01
26	Sick Person	19.8	22.2	
27	Stab/Gunshot/Penetrating Trauma	0.1	0	
28	Stroke (CVA)	1.3	1.2	
29	Traffic/Transportation Accident	5.6	4.1	
30	Traumatic Injury (specific)	1.2	1.7	
31	Unconscious/Fainting (near)	3.6	2.8	
32	Unknown Problem (man down)	7.6	9.3	
33	Transfer/Interfacility/Palliative	1.7	1.4	
34	Other	0.6	0.2	

Because total call volume increased during the storm, five types (back pain, cardiac or respiratory arrest, falls, stroke, and emergency transfer) that underwent an increase in number of calls nonetheless underwent a decrease in proportion of total calls, although none of these differences was statistically significant. Similarly, in four cases (abdominal pain, diabetic problems, sick person, and unknown problem) statistically significant increases in number of calls became statistically insignificant increases in percentage of total volume. There were therefore only two types—carbon monoxide and pregnancy—whose increases in call number and in proportion of total calls were both statistically significant. In three cases (overdose/poisoning, psychiatric and other types), statistically insignificant decreases in number of calls became statistically significant decreases in proportion of calls due to the higher volume during the storm.

ALS Treatment Analysis:

As shown in **Figure 8**, the databases yielded 3,251 ALS transports between 1/25/13 and 2/27/13. ALS transports increased slightly during the storm (522 in the storm vs. 500 in the control, $p=0.57$). However, calls with an ALS intervention decreased (215 in the storm vs. 233 in the control, $p=0.41$). The rate at which ALS units performed an intervention decreased from 46.6% in the control to 41.2% in the storm ($p=0.09$). **Figure 9** shows how this rate fluctuated by day during the study period.

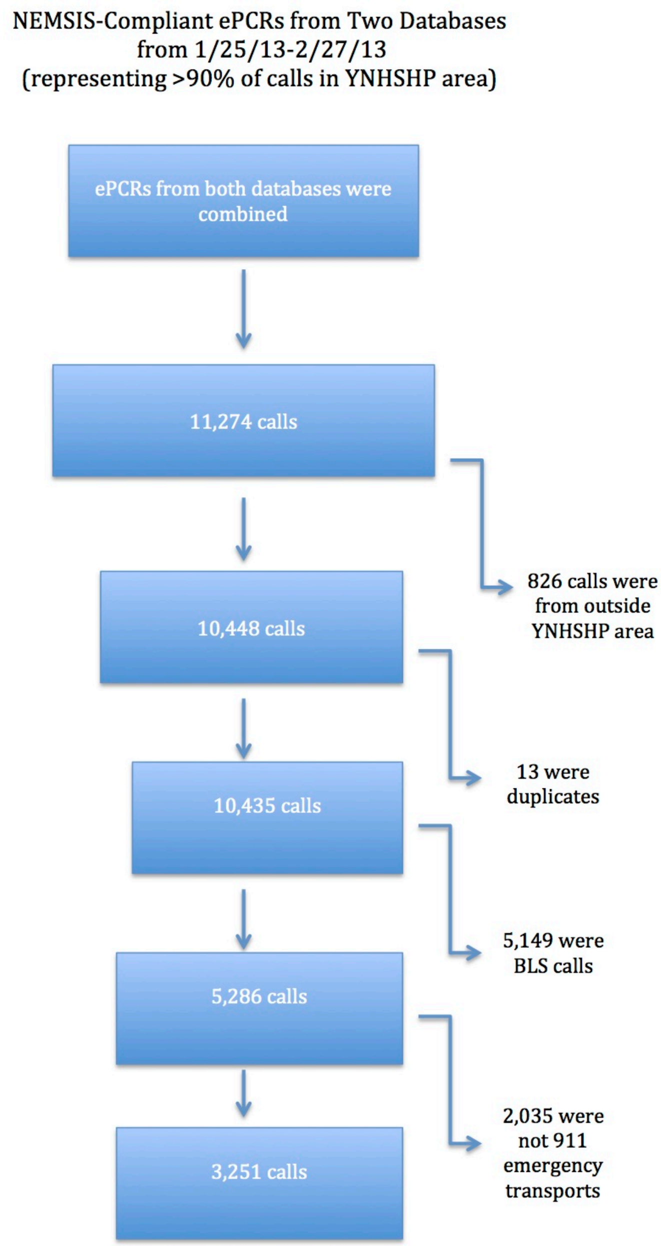


Figure 8. Steps for how the two databases were filtered to obtain ePCRs for ALS transports in the YNHSHP area during the study period. Of note, the 5,149 BLS calls that were excluded include both emergency transports and non-emergency transfers therefore the data do not suggest that the number of transports from the databases exceeds the total number of emergency calls obtained from CMED for the same period.

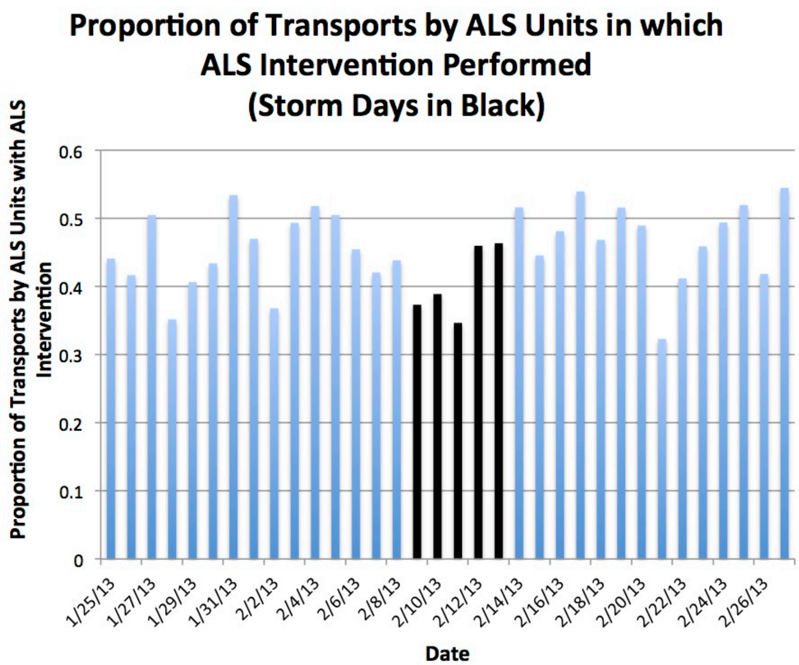


Figure 9. Proportion of transports by ALS units in which an ALS intervention was performed.

In the analysis of calls in which a specific ALS intervention was performed, there were no statistically significant differences during the storm. In both the storm and the control, the most prevalent intervention was IV access (successfully obtained or attempted). Across the study period, it was performed in 1,257 of the 3,251 calls in which an ALS unit transported (38.7%). The next most prevalent was twelve-lead ECG performance, which was done 623 times (19.2% of all ALS transports). **Table 4** shows differences during the storm for interventions where sufficient data were available for analysis.

Table 4. Differences in Number of Calls in which Specific Interventions Performed

ALS Intervention	N/day (Control)	N/day (Storm)	p value
IV Access	38.2	33.7	0.12
12 Lead	18.2	20.6	0.5
Neb Meds	4.7	3.8	0.23
Aspirin	5.3	6.3	0.51
Nitroglycerin	3.8	4.8	0.51
Intubation	0.7	0.2	0.08
IV Medication	7	6.7	0.71

Discussion

During the blizzard period, the EMS system in the YNHSHP area experienced a significant increase in call volume. As shown in **Figure 3**, call volume was roughly average while the snow fell (2/8/13-2/9/13) and then peaked the following the day (2/10/13) before gradually decreasing each day for the remainder of the storm period. In contrast to Levy et al.'s (29) suggestion that emergency call volume was sufficiently low during a blizzard such that ambulance crews could be repurposed for transporting discharged patients home from the hospital, these data suggest that full staffing levels are needed for 911 calls in the YNHSHP area during the snowfall portion of a blizzard.

Also, a distinction must be made between these data and the models of Kunkel and McLay (25) who associate high call volume with snowfall but do not specify how much accumulation is assumed in their "blizzard" model. It is likely that for the snowfall portion of a blizzard, accumulation and call volume increase together up to a point, but that higher accumulations force potential patients indoors and off the roads, ultimately causing call volume to plateau or lessen. The sustained increase in call volume for several days after the storm reinforces the message of earlier researchers (9, 13) that the effects on the healthcare system of blizzards must be understood as occurring for an extended period after snowfall ceases. **Figure 5** demonstrates that with the exception of Saturday, 2/9/13, the call volume on each storm day was more than two standard deviations greater than the mean for that day of the day in the control period. **Figure 4** demonstrates the call volume increase during the busiest daily six-hour segment, 12:00-17:59. Plans for future blizzards should include staffing to meet this daily surge.

Of the seven call types that increased significantly during the storm, several deserve special attention. The significant increase in calls for breathing problems (call type 6) is consistent with significant increases in such calls seen during the NYC blackout (32) and Hurricane Ike (31). This is especially important given that these calls represented a sizable proportion of overall volume during the blizzard (12.7%) and potentially involved high acuity patients. Because calls for breathing problems are seen to increase in several types of disasters, it can be suggested that this increase is reflective of a disaster situation with high call volume and not necessarily a blizzard in particular. The fact that calls for breathing problems as a percent of total calls stayed effectively the same (12.6% vs 12.7%) further supports that this increase is born generally from an overall increase in call volume. Furthermore, the data from Thorns et al. (27) did not conclusively show an increase in calls for breathing problems during periods of snowfall.

Although symptomatic asthma and COPD comprise only a portion of possible calls for breathing problems, the slight (albeit statistically insignificant) decrease in calls with administration of nebulized medications during the storm suggests that the increase in calls for breathing problems does not necessarily mean that more patients had high acuity breathing problems. This is consistent with the prediction of McLay et al. (24) that the increase in call volume during a severe weather event is not matched by a proportionate increase in acuity. It is also possible that some of the calls for breathing problems during the storm were for ventilator or other mechanically dependent patients. This vulnerable population relies on technology that provides life-sustaining treatment outside of a hospital. Absence of power during a storm could prompt calls to 911 that would be categorized as breathing problems. Unfortunately, this study cannot differentiate these patients from others who utilized EMS for breathing problems.

The increase in calls for diabetic problems (call type 13) was very dramatic ($p=0.007$) and similar increases in such calls have not been reported in other types of disasters or in association with snow. However, other researchers may not have been looking for these calls directly (indeed, FDNY does not have a specific call type for diabetic problems and such patients would be subsumed in other categories for medical illness). The reasons for this increase deserve further study. One likely contributing factor is that these patients are especially dependent on consistent access to grocery stores and pharmacies in order to have the proper food and medication to keep their blood glucose at a safe level. During the blizzard, routine shopping trips were greatly hindered by road conditions and some stores remained closed for several days. Studies of past disasters have implicated such disruptions in poor health outcomes for diabetic patients that are manifest both in the immediate aftermath of the disaster and in the long term (38). Given that diabetes and chronic kidney disease are often comorbid conditions, it is also possible that some 911 calls from dialysis patients who had missed dialysis appointments were classified as diabetic problems. As suggested by Dent et al. (35), these patients would likely benefit from receiving dialysis ahead of schedule before a storm. During a blizzard, EMS may be able to help without squandering limited resources by arranging for non-ambulance transport vehicles (such as sport utility vehicles with four-wheel drive) to be made available to bring these patients to and from dialysis. Local registries of dialysis patients could be used to arrange carpools that would optimize efficiency. This is an important example of how EMS providers can collaborate with other facets of the public health infrastructure during disasters.

The increases in calls for carbon monoxide exposure (call type 8) and pregnancy concerns (call type 24) were the only two to remain statistically significant as increases in percent of total calls (see **Table 3**). The increase in carbon monoxide calls is consistent with increased ED visits for CO that were seen after the 1978 blizzard (13) and some of these calls undoubtedly contributed to the dataset gathered by Johnson-Arbor (11) in her study of CO cases across Connecticut during the blizzard. The increase in calls for pregnancy concerns has not been previously reported in association with disasters or snow. Although further study is certainly needed, this increase may reflect the inability of otherwise healthy pregnant women to travel to the hospital in private vehicles in order to give birth due to road conditions. Most EMS providers encounter calls for CO exposure and pregnancy concerns (especially imminent childbirth) infrequently. Because the overall number of these calls and their proportion of total volume remained low during the blizzard, it is unlikely that they significantly affect staffing considerations. However, it may be useful for EMS agencies to provide refresher education about these unique emergencies before blizzards with the appreciation that providers are more likely to encounter such patients. Also, given that CO exposure incidents often involve multiple patients who need oxygen, it may be beneficial before a forecast blizzard to equip a response vehicle with multiple oxygen canisters and regulators so that it can deploy to a CO incident and supplement the resources of the responding EMS crew. Public Service Announcements (PSAs) before a storm can also remind the public to ensure that home heating systems and car tailpipes remain properly vented.

The increase in calls for unknown problems (call type 32) is very significant ($p=0.02$) and these calls comprised 9.3% of overall volume during the blizzard. It is unfortunate that so many calls could not be better categorized by dispatchers because these calls could have contributed to better understanding of differences in the other 33 call types into which the calls would have otherwise been placed. However, cognizant of Auf der Heide's (22) warnings about the difficulties of researching disasters, it must be appreciated that during this period of increased volume, emergency dispatchers likely had less time to ascertain enough information to more accurately categorize a call and thus the increase for the unknown call type.

Although neither calls for chest pain (call type 10) nor heart problems/AICD (call type 19) increased significantly during the storm, the combination of these calls into a group that better captures all cardiac-related emergencies resulted in a significant increase ($p=0.007$). This is consistent with all of the blizzard data from 1978 and 1996 that showed a significant increase in ED visits, hospital admissions, and death due to ischemic heart disease during blizzards. (This study was not designed to look at the extent to which snow shoveling may have contributed to this increase.) Furthermore, although data were not sufficient for statistically significant results, the only three individual ALS interventions that were performed during more calls in the storm than in the control—twelve-lead ECG, nitroglycerin administration and aspirin administration—all pertain to the treatment of patients with suspected acute coronary syndrome. This is in contrast to the increase in calls for breathing problems where more calls did not appear to translate into more ALS intervention for that problem. Importantly, it must be remembered that calls for chest pain increased during the NYC blackout and Hurricane Ike therefore further study is still needed to determine the extent to which calls for chest pain increase generally in disasters versus the extent to which they increase specifically in blizzards.

Of the call types that represent patients with traumatic injury, several increased insignificantly during the storm (call types 17, 21 and 30), two decreased (4 and 29) and two provided insufficient data for analysis (7 and 27). When analyzed in aggregate, calls for trauma increased insignificantly during the blizzard. This data therefore provides little insight into how the discussion of trauma admissions in snow (10,15,16,17) is reflected in EMS utilization.

Given that overall call volume increased so dramatically during the blizzard, the call types that countered this trend and decreased deserve special notice as well. The only call type to decrease significantly was for assault (call type 4). This type represents a very small amount of total volume but this decrease does suggest a decrease in EMS use for victims of interpersonal violence during the storm. This is consistent with the findings of Michel et al. (20) that emergency department visits for intentional injury decrease during snowfall. It is in contrast to the NYC blackout when EMS calls for gunshot victims increased significantly (32).

The decrease in psychiatric calls (call type 25) was noteworthy although not quite statistically significant (20 calls per day vs. 14 calls per day, $p=0.06$). A decrease in ED visits for such patients was hypothesized in the study of the 1996 blizzard (9), but was not seen. The reason why calls for psychiatric patients decreased deserves further study. It has previously been explained that disasters disrupt the framework of substance abuse treatment programs that often help many patients with psychiatric problems (39). However, this would likely lead to an increase in EMS utilization that may manifest only at the end of a storm period when continued disruption in services begins to lead to cases of drug overdose or withdrawal. It is possible that whereas many psychiatric calls are made by third parties who witness someone behaving abnormally outside or in a public place, the blizzard kept enough potential patients and callers off the streets and out of work that fewer of these calls were made. Interestingly, a decrease in psychiatric calls also occurred during the NYC blackout (32).

In regard to the ALS intervention analysis, there was a decrease in the rate at which transporting ALS units performed an ALS intervention during the storm. This decrease was convincing, although it did not reach statistical significance (p=0.09). Although this study was not designed to directly assess the severity of patient conditions during the storm, the decrease in rate of ALS interventions may at least suggest that paramedics did not have to contend with any dramatic increase in patient acuity during the storm. It is also possible, however, that increased response times and poor road conditions resulted in more ALS units being sent to what would otherwise be BLS calls (and perhaps vice versa) and this could explain why relatively fewer interventions were performed. It is also possible that the "intrinsic system adaptation" predicted by Kunkel and McLay (25) was partially illustrated by ALS units performing interventions less frequently in order to more rapidly bring patients to the ED and return to service to meet the high call volume demand. This would explain **Figure 9**, which shows that the rate of ALS intervention was the lowest for the first three full days of the storm (2/9/13-2/11/13) before returning closer to normal for the final two days (2/12/13 and 2/13/13) as the system returned to normal.

Ultimately, this study does not *explain* why certain call types increased or decreased or why the rate of ALS intervention dropped during the storm. However, a clear message of this study is that call volume during the blizzard dramatically increased and that staffing for future blizzards must be sufficient to meet this demand, especially during the busy afternoon shift. The relative decrease in ALS interventions suggests that the bulk of this extra demand can be met by deploying more BLS ambulances and that increasing the number of ALS ambulances as well as the amount of equipment on ALS ambulances may not be necessary.

Limitations

This study is limited by deficiencies in data gathering and analysis at several junctures. First, in regard to the call types analysis, not all calls in the YNHSHP area properly arrived in CMED. There were calls (perhaps several dozen) during the worst of the snowfall for which no ambulance was ever dispatched because none was available and consequently no record was made in CMED (personal communication). For example, a news article describes a call at 22:00 on 2/8/13 in New Haven in which firefighters transported a pregnant woman to the hospital in their truck because no ambulances were available (the woman delivered a healthy child shortly after arriving at the hospital) (40). No record of this call exists in the CMED database. Attempts to gather records of such calls from other sources were unsuccessful.

Second, analyzing dispatcher-generated call types is an imprecise window into the actual patient conditions that prompted EMS calls. Call types are sometimes wrong and many patient conditions could reasonably fall into multiple call types. (For example, a patient with diabetes who faints due to hypoglycemia and strikes his head on the ground could be reasonably categorized as “diabetic problems,” “unconscious/fainting” or “falls.” If the dispatcher is harried or the caller is imprecise, it may be marked as "unknown.") Nonetheless, analysis of call types is the most common method of assessing EMS demand and provides adequate, standardized insight. Future researchers may wish to develop registries of ambulance patients using ePCRs so that patient condition is determined directly from the treating provider and not the EMS dispatcher.

Third, in regard to the ALS treatment analysis, the two databases combined do not provide documentation of all transports in the YNHSHP area. Specifically, transports from North Branford are underrepresented as the town does not use either database. (There are several calls recorded in database two where units from another town entered North Branford as mutual aid.) However, the population of North Branford comprises only 3.5% of the total population of the YNHSHP area so this missing data is unlikely to meaningfully affect overall results.

Fourth, as noted in the methods section, the first database does not include RMAs, cases in which a patient is pronounced dead in the field, and other calls that do not culminate in an ED transport. To maintain consistent analysis, such calls were filtered from the second database as well. These calls certainly represent a substantial use of EMS resources, but only a relatively small amount of ALS utilization (e.g. treatment for a cardiac arrest patient who is ultimately pronounced dead prehospitally or administration of dextrose to a hypoglycemic patient who then chooses to RMA). However, these calls comprise a small proportion of the second database and could safely be discounted.

Fifth, ePCRs may not appropriately include all the interventions that paramedics performed. This error may be systematic during the storm, if one hypothesizes that the stress of increased call volume and difficult working conditions resulted in fewer interventions being documented, contributing to the observation that the rate of ALS intervention decreased. This hypothesis is merely speculative and there is no way to independently test it.

Sixth, it is possible that the paramedics who happened to be working during the storm had different practice patterns from paramedics who worked during the control. The study attempted to mitigate against this by using the same days of the week and times of day for the control, with the appreciation that most paramedics work the same shifts each week. Additionally, the storm period was sufficiently long at five days and six hours that most, if not all, regularly working paramedics were on the ambulance for at least some of the time.

Seventh, and finally, it is important to appreciate that the results of research into one EMS system often differ greatly from the results for another EMS system (41). These results should be understood best to pertain to a specific blizzard in the YNHSHP area in southern Connecticut and should be applied only with caution to other jurisdictions.

Despite these limitations, this study demonstrated a dramatic increase in EMS call volume for five days after a major snowfall. Planning for future blizzards should include sufficient staffing to meet this increase, especially during afternoons. The decrease in the rate at which paramedics performed interventions suggests that the increased volume was due mostly to a spike in lower acuity calls. The increased staffing needs can therefore likely be met primarily with more basic life support ambulances. Significant increases in calls for diabetic problems and pregnant women highlight the need for EMS to work with other facets of the public health infrastructure to best serve vulnerable populations during disasters. Future research should examine whether these results are replicated in other blizzards to help determine which findings are specific to blizzards and which are common to disasters with increased EMS usage. EMS agencies may also seek to devise, implement and study plans to help specific populations whose needs increase and change during disasters.

References

1. Shelton, J. (2013, February 9). Connecticut Digs Out from Blizzard; Some Towns Buried Under 3 Feet of Snow. *New Haven Register*. Retrieved from www.nhregister.com

2. Connecticut Department of Energy and Environmental Protection (2015). Connecticut's Weather Fun Facts. Retrieved from www.ct.gov

3. Bendici, R. (2015, January 25). A Look Back at Wicked Connecticut Winters and the Big Blizzards. *Connecticut Mag*. Retrieved from www.connecticutmag.com

4. *WFSB* Staff. (2013, February 11). New Haven PD Sets up Checkpoints to Enforce Travel Ban. *WFSB*. Retrieved from www.wfsb.com

5. Na, C., Wang, S., Jin, H., Stuntz, M., and Bogucki, S. 2014. The Effect of a Winter Storm on Emergency Medical Services. *J Occup Env Med*. (Abstr.)

6. Strauch, G.O. 1973. Major abdominal Trauma in 1971. A study of Connecticut by the Connecticut Society of American Board Surgeons and the Yale Trauma Program. *Am J Surg*. 125(4): 413-418.

7. Van Gelder, C.M., and Bogucki, S. 2005. Emergency Medical Services in Connecticut. *Prehosp Emerg Care*. 9(2): 219-226.

8. Connecticut Department of Public Health. 2013. Estimated Populations in Connecticut as of July 1, 2013. Retrieved from www.ct.gov

9. Blindauer, K.M., Rubin, C., Morse, D.L., and McGeehin, M. 1999. The 1996 New York Blizzard: Impact on non-injury emergency visits. Am J Emerg Med. 17(1): 23-27.

10. Ali, A.M., and Willet, K. 2015. What is the effect of the weather on trauma workload? A systematic review of the literature. *Injury*. 46(6): 945-953.

11. Johnson-Arbor, K.K., Quental, A.S., and Li, D. 2014. A comparison of carbon monoxide exposures after snowstorms and power outages. *Am J Prev Med*. 46(5): 481-486.

12. Glass, R.I., O'hare, P., and Conrad, J.L. 1979. Health consequences of the snow disaster in Massachusetts, February 6, 1978. *Am J Public Health*. 69(10): 1047-1049.

13. Faich, G., and Rose, R. 1979. Blizzard Morbidity and Moratlity: Rhode Island, 1978. *Am J Public Health*. 69(10): 1050-1052.

14. Glass, R.I., and Zack, N.M. Jr. 1979. Increase in deaths from ischemic heart-disease after blizzards. 1979. *Lancet*. 1(8114): 485-487.

15. Bhattacharyya, T., and Millham, F.H. 2001. Relationship between weather and seasonal factors and trauma admission at a Level I trauma center. *J Trauma*. 51(1): 118-122.

16. Rising, W.R., O'Daniel, J.A., and Roberts, C.S. 2006. Correlating weather and trauma admissions at a Level I trauma center. *J Trauma*. 60(5): 1096-1100.

17. Ho, V.P., Towe, C.W., Chan, J., and Barie, P.S. 2015. How's the weather? Relationship between weather and trauma admissions at a Level I trauma center. *World J Surg*. 39(4): 934-939.

18. Bernstein, S.L., Rennie, W.P., and Alagappan, K. 1994. Impact of Yankee Stadium Bat Day on blunt trauma in northern New York City. *Ann Emerg Med*. 23(3): 555-559.

19. Gamble, J.L., and Hess, J.J. 2012. Temperature and Violent Crime in Dallas, Texas: relationships and implications of climate change. *West J Emerg Med*. 13(3): 239-246.

20. Michel, S.J., Wang, H., Selvarajah, S., Canner, J.K., and Murril, M., et al. 2016. Investigating the relationship between weather and violence in Baltimore, Maryland, USA. *Injury*. 47(1): 272-276.

21. Connecticut General Assembly. (2013, July 11). An Act Requiring Working Smoke and Carbon Monoxide Detectors in Certain Residential Buildings at the Time Title is Transferred. Retrieved from www.cga.ct.gov

22. Auf der Heide, E., 2006. The importance of evidence-based disaster planning. *Ann Emerg Med*. 47(1): 34-49.

23. Wong, H.T., and Lai, P.C. 2014. Weather factors in the short-term forecasting of daily ambulance calls. Int J Biometeorol. 58(5): 669-678.

24. McLay, L.A., Boone, E.L., and Brooks, J.P. 2012. Analyzing the volume and nature of emergency medical calls during severe weather events using regression methodologies. *Socio-Economic Planning Sciences*. 46: 55-66.

25. Kunkel, A., and McLay, L.A. 2013. Determining minimum staffing levels during snowstorms using an integrated simulation, regression and reliability models. *Health Care Manag Sci*. 16(1): 14-26.

26. Nick, G.A., Savoia, E., Elqura, L., Crowther, M.S., and Cohen, B., et al. 2009. Emergency Preparedness for vulnerable populations: people with special health-care needs. *Public Health Rep*. 124(2): 338-343.

27. Thorns, J.E., Fisher, P.A., Rayment-Bishop, T., and Smith, C. 2014. Ambulance call-outs and response times in Birmingham and the impact of extreme weather and climate change. *Emerg Med J*. 31(3): 220-228.

28. Kaiser, C. (2011, June 15). EMS Agency Plans for Natural Disasters. *JEMS*. Retrieved from www.jems.com

29. Levy, J.L., Seaman, K., and Levy, M.J. 2011. A novel intervention for decreasing hospital crowding following the blizzards of 2010. *Am J Disaster Med*. 6(4): 255-258.

30. Vencloviene, J., Babarskiene, R., Dobozinskas, P, and Siurkaite, V. 2015. Effects of weather conditions on emergency ambulance calls for acute coronary syndromes. *Int J Biometeorol*. 59(8): 1083-1093.

31. Cooper, E., Langabeer, J.R. 2nd, Alqusairi, D., Persse, D. 2012. Impact of Hurricane Ike on the call volumes of Houston Fire Department emergency medical services. *Am J Disaster Med*. 7(2): 137-144.

32. Freese, J., Richmond, N.J., Silverman, R.A., Braun J., and Kaufman B.J., et al. 2006. Impact of a citywide blackout on an urban emergency medical services system. *Prehosp Disaster Med*. 21(6): 372-378.

33. Jan, S., and Lurie, N. 2012. Disaster resilience and people with functional needs. *N Eng J Med*. 367(24): 2272-2273.

34. Ochi, S., Hodgson, S., Landeg, O., Mayner, L., and Murray, V. 2014. Disaster-driven evacuation and medication loss: a systematic literature review. *PLoS Curr*. 18:6.

35. Dent, L., Finne, K., and Lurie, N. 2015. Progress in emergency preparedness for dialysis care 10 years after Hurricane Katrina. *Am J Kidney Dis*. 66(5): 742-744.

36. Haeri, S., and Marcozzi, D. 2015. Emergency preparedness in obstetrics. *Obstet Gynecol*. 125(4): 959-970.

37. Ewing, B., Buchholtz, S., and Rotanz, R. 2008. Assisting pregnant women to prepare for disaster. *MCN Am J Matern Child Nurs*. 33(2): 98-103.

38. Fonseca, V.A., Smith, H., Kuhadiya, N., Leger, S.M., and Yau, C.L et al. 2009. Impact of a natural disaster on diabetes: exacerbation of disparities and long-term consequences. *Diabetes Care*. 32(9): 1632-1638.

39. Maxwell, J.C., Podus, D., and Walsh, D. 2009. Lessons learned from the deadly sisters: drug and alcohol treatment disruption, and consequences from Hurricanes Katrina and Rita. *Subst Use Misuse*. 44(12): 1681-1694.

40. Appel, A. (2013, February 11). That Baby wasn't Waiting. *New Haven Independent*. Retrieved from www.newhavenindependent.org

41. O'connor, R.E., and Cone, D.C. 2009. If you've seen one EMS system, you've seen one EMS system… *Acad Emerg Med*. 16(12): 1331-1332.